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AFFORESTING FORMER AGRICULTURAL LANDS WITH HIGH VALUE HARDWOODS IN SOUTHERN ONTARIO

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Abstract: With the onset of another environmental revolution, interest in establishing afforested plantations on marginal farmland in southern Ontario has been renewed. To supply private landowners with the tools needed to afforest their land in a successful, cost effective manner, we must first address the technical knowledge gap that exists in a regional context.

This study was a side by side comparison between traditional afforestation practices and alternative techniques that we feel may address some of the common obstacles to modern afforestation. The study investigated the influence of two planting types (planted and seeded) and three vegetation management regimes (plastic mulch, herbicide and control) on the growth and development of black cherry (*Prunus serotina* Ehrh.), bur oak (*Quercus macrocarpa* Michx.) and red oak (*Quercus rubra* L.) plantations in the London Ontario region. The analysis of the three year results found plastic mulch to be an effective alternative to herbicide use, without the annual application commitment. Red oak was identified as an appropriate tree species for afforestation. However, the success of bur oak was limited by site quality and hydrology. Planted black cherry was identified as an appropriate candidate for afforestation because it can quickly occupy and persist in an open field environment. Although the seeded oak species did produce a high proportion of successful germination, a clear conclusion on the success of direct seeding was unable to be formed due to the age of our plantations.

Keywords: black cherry, bur oak, direct seeding, herbicide, planting, plastic mulch, red oak.

INTRODUCTION

Afforestation, as defined by the Kyoto protocol, is the direct, human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and /or the human-induced promotion of natural seed sources (UNFCCC 2002). Afforestation has not been widely adopted in southern Ontario. The elimination of tree planting subsidies in the early 1990s made afforestation a risky and expensive practice for Ontario farmers. As a result, afforestation began a consistent decline (White and Kruz 2005) and research and development into improved and more cost effective methods were also abandoned.

With the onset of another environmental revolution, a renewed interest in establishing afforested plantations has surfaced. Recent government incentives, such as the $20 million dollar Forest 2020 initiative and the 50 million tree program, are encouraging Ontario landowners to afforest their land for carbon sequestration (Newmaster *et al.* 2006). Such incentives have farmers and private land owners across Canada actively afforesting their land.

In southern and eastern Ontario alone there are over 900,000ha of abandoned marginal farmland eligible for afforestation. Creating a program that can successfully afforest these lands begins with addressing the considerable knowledge gap that exists in the field of afforestation. Efficient and cost effective methods for afforesting farmland with high value hardwoods must be investigated in a regional context. This study aimed to address some of the financial and social obstacles of afforestation by comparing traditional practices with proposed alternatives. The study investigated the influence of two planting types (planted and seeded) and three vegetation management regimes (plastic mulch, herbicide and control) on the growth and development of black cherry (*Prunus serotina* Ehrh.), bur oak (*Quercus macrocarpa* Michx.) and red oak (*Quercus rubra* L.) plantations in the London Ontario region. Our objectives are to 1) assess direct seeding as a successful alternative to planting nursery stock; 2) assess plastic mulch as an effective vegetation management alternative to herbicide use; 3) assess the suitability of black cherry, bur oak and red oak to afforestation of former agricultural fields.

MATERIALS AND METHODS

Study Site and Experimental Design

Three study sites of approximately 1 ha were established at the Pittock Conservation Area, Fingal Wildlife Management Area and Littlejohn Farm outside of London Ontario in the spring of 2006. The soil texture class was silty sand at the Pittock site and silty loam at the Fingal and Littlejohn sites. To provide a receptive seed bed each site was disked and ploughed the fall prior to planting. An electric fence surrounded each site to discourage deer browsing. Within each site, fifty-four completely randomized 100m^2 square plots were arranged in a 2x3x3x3 factorial design. Factors consisted of:

- Planting method (direct seeding, planting)
- Tree species (red oak, bur oak, black cherry)
- Vegetation control type (no control, simazine/round up, plastic mulching)
- Replications (3)

The 10m x 10m plot contained three rows of five planting locations with a between row spacing of 3m to facilitate mowing. Mowing is a common means of controlling competing vegetation in an afforested plantation. All outer planting locations were situated 1m from the plot's edge and the perimeter of each plot was treated with simazine to reduce edge effects. Seeds were collected in the fall of 2005, sealed in plastic bags and refrigerated overwinter. Planting occurred the following spring from April 30th to May 6th. The oak seeds were planted at a depth of 2cm at a density of 3-5 seeds per planting location. The smaller black cherry seeds were planted at a density of 10-15 seeds per location. The bare root 2+0 red oak, 1+0 bur oak and 1+0 black cherry seedlings were carefully planted to ensure natural root system development. Simazine treatments occurred in May of 2006 at a rate of 5.68kg/ha at the Pittock site and 7.8kg/ha for the other two sites. A second application occurred in November of 2006 for the Fingal and Littlejohn sites and in April 2007 at the Pittock site.

Measurements and Analysis

Germination, survival and seedling height were collected for all planting locations in the spring and fall of each year from 2006 to 2008. Root collar diameters (RCD) were collected for a randomly selected plot for each treatment at each site in the fall of 2008. For analysis, height growth was converted to an increment to provide a standard platform for comparison between planted and seeded treatments. To avoid confounding the results by including the random termination of cases, negative growth increments exceeding -10cm between time steps were removed from the analysis. To eliminate errors in the transformation as a result of zeros and negative numbers a constant of 11cm was added to each case. The data was then Log10 transformed to fit a normal distribution. A repeated measures ANOVA with three time steps was conducted on the incremental height growth accompanied by a Scheffe post hoc test. Survival and germination proportions were calculated separately at the plot level. The square root transformed survival and germination data were analysed using a repeated measure ANOVA procedure with six time steps. Root collar diameter measurements were analysed using a univariate ANOVA procedure. All analysis was performed in SPSS version 16.0.

RESULTS

Germination

Germination was highly varied between sites (Figure 1a). The final measurement at the Pittock site had the greatest proportion germinated (0.69) and was statistically similar (α=0.05) to the Fingal results (Table 1). The Littlejohn site yielded the poorest results with a peak germination proportion of 0.43 in fall 2008. Over time, the vegetation management regime proved to have a significant impact on germination capacity (Table 1), although by fall 2008 those differences seem to be resolved (Figure 1b). Due to the poor results in the first three time steps, the plastic mulch treatment produced significantly lower results than the other two treatments. The black cherry data was removed from analysis because it was generally unsuccessful. The seeded red oak had a higher germination success than bur oak (Figure 1c).

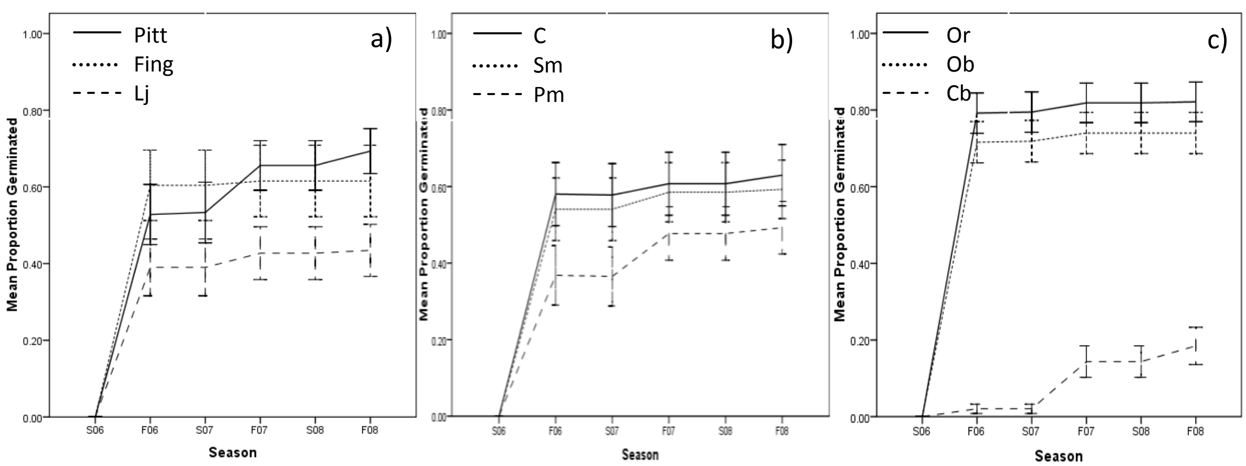


Figure 1: Average germination proportions plotted over a three year time horizon with standard error bars. a) Site b) Vegetation management regimes c) Species.

Table 1: Main effects repeated measures ANOVA results (α=0.05) for average germination proportions of seeded plots.

Source of variation	df	MS	*F*	*P*
Site	2	0.873	13.136	≤0.000
Species	1	0.137	2.063	0.161
Management	2	0.529	7.957	0.002
Site*Species	2	0.153	2.301	0.117
Site* Management	4	0.133	2.004	0.118
Species* Management	2	0.053	0.800	0.458
Site*Species* Management	4	0.070	1.050	0.397
Error	32	0.066	.	.

Survival

Survival of planted seedlings proved to be a very sensitive response variable (Table 2). By fall 2008 all three sites and all three species were producing significantly different survival results (Figure 2a, c). Average survival proportions varied from 0.44 to 0.87 depending on the treatment. The vegetation management post hoc test revealed that the herbicide treatment was similar to the other two treatments but the plastic mulch treatment yields were significantly higher than the control (Figure 2b).

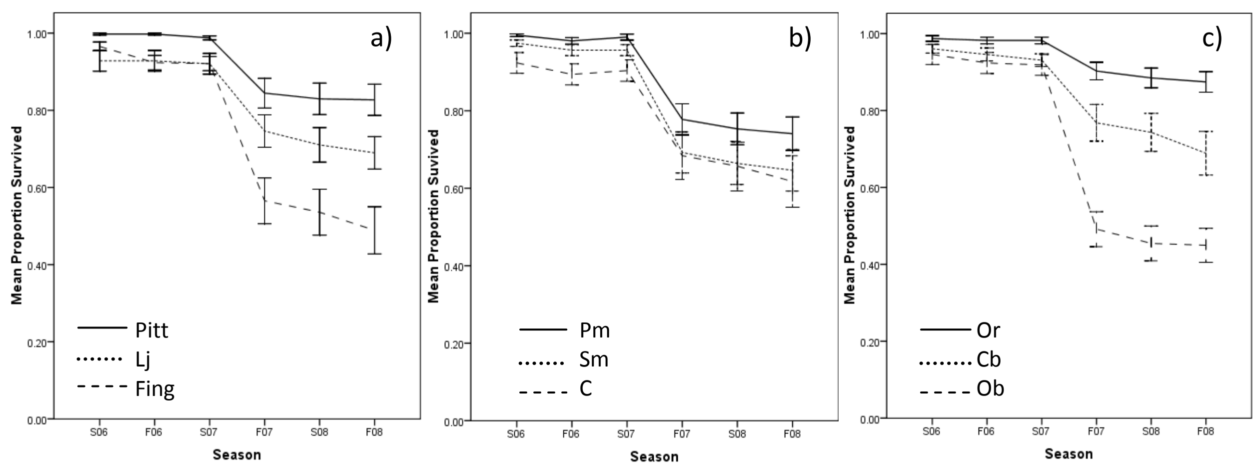


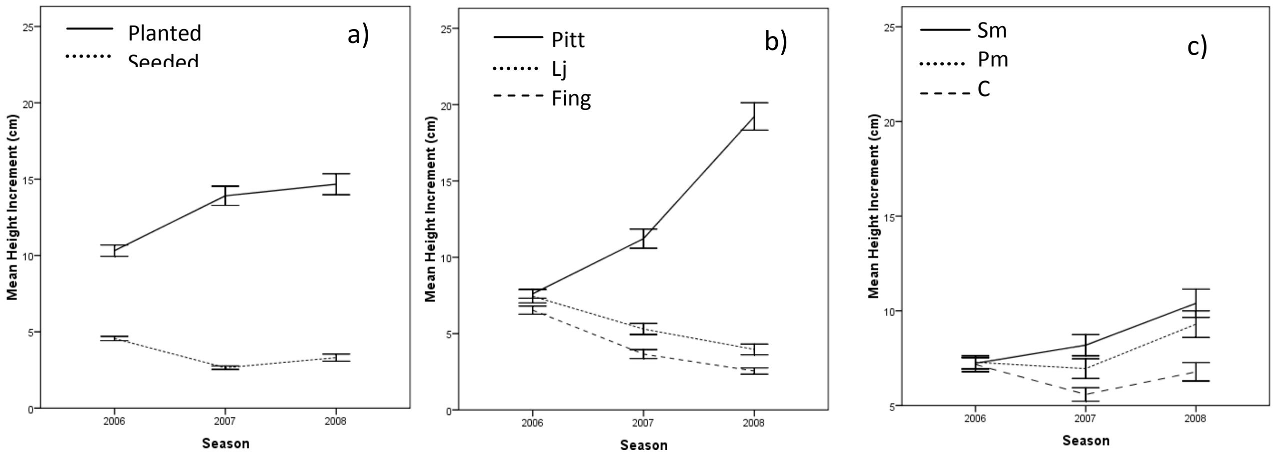
Figure 2: Average survival proportions plotted over a three year time horizon with standard error bars. a) Site b) Vegetation management regimes c) Species.

Table 2: Main effects repeated measures ANOVA results (α=0.05) for average survival proportions of planted plots.

Source of variation	df	MS	*F*	*P*
Site	2	0.658	17.879	≤0.000
Species	2	0.999	27.163	≤0.000
Management	2	0.203	5.507	0.007
Site*Species	4	0.114	3.102	0.023
Site*Management	4	0.052	1.412	0.243
Species*Management	4	0.066	1.785	0.146
Site*Species*Management	8	0.015	0.397	0.918
Error	53	0.037	.	.

Height Increment

The height increment results (Table 3) indicate site (Figure 3b) was highly significant, influencing not only the results of the main effects but the interaction terms as well. While the Littlejohn and Fingal sites saw a consistent decline, incremental height growth increased dramatically at the Pittock site. A difference is also seen between planting types (Figure 3a). Planted trees had significant advantage over seeded trees after three seasons. The incremental growth increased for planted trees while it decreased for seeded trees. Due to the slow growth of the tolerant hardwood species such a result is expected. The species term (Figure 3d) identified black cherry as the species that produced the greatest height increment as of fall 2008. Red oak had an incremental growth significantly less than black cherry but greater than bur oak. Through time the vegetation management term produced an insignificant variation in average incremental height growth. By the third season the mulching and herbicide treatments are began to separate themselves as superior treatments to the control.



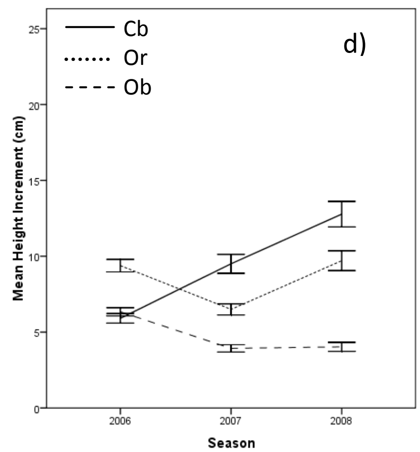


Figure 3: Mean incremental height growth plotted over a three year time horizon with standard error bars. a) Planting Type b) Site c) Vegetation management regimes d) Species

Table 3: Main effects repeated measures ANOVA results (α=0.05) for average incremental height growth.

Source of variation	df	MS	*F*	*P*
Site	2	6.295	140.915	≤0.000
Plant	1	5.730	128.284	≤0.000
Species	2	0.645	14.428	≤0.000
Management	2	0.070	1.570	0.209
Site * Plant	2	0.835	18.683	≤0.000
Site * Species	4	0.724	16.213	≤0.000
Site * Management	4	0.342	7.646	≤0.000
Plant * Species	2	2.061	46.145	≤0.000
Plant * Management	2	0.011	0.246	0.782
Species * Management	4	0.063	1.418	0.226
Site * Plant * Species	3	0.195	4.359	0.005
Site * Plant * Management	4	0.064	1.439	0.219
Site * Species * Management	8	0.105	2.361	0.016
Plant * Species * Management	4	0.089	1.985	0.094
Site * Plant * Species * Management	5	0.093	2.088	0.064
Error	1261	0.045	.	.

Root Collar Diameter

In the planted model for RCD all terms were significant (Table 4). Profile plots (Figure 4) of the site, species and management terms show the Pittock site consistently producing higher RCD. Bur oak remained the species that is less productive while the vegetation management treatments produce comparable results. Post hoc tests for planted and seeded trees were consistent with the discoveries of the height increment tests. However, contrary to the aforementioned tests, the simazine application separated out as producing a significant improvement on RCD growth.

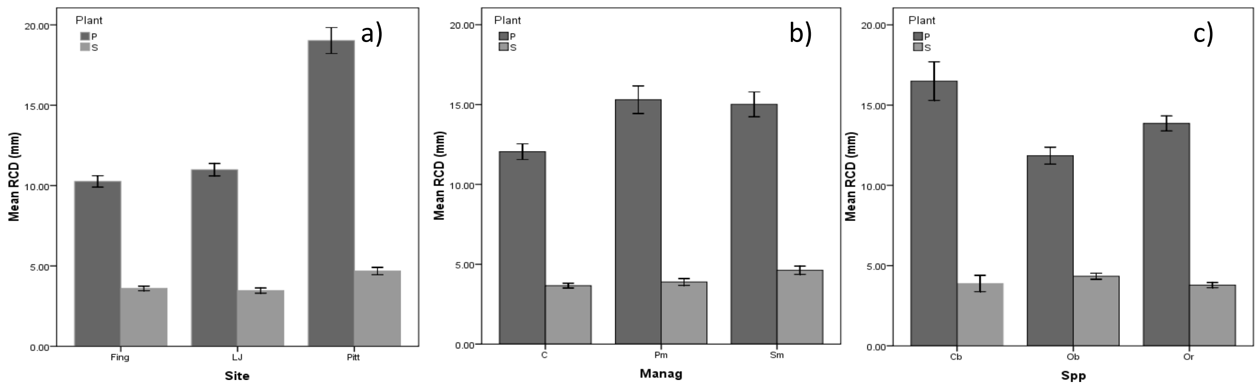


Figure 4: Average root collar diameter growth in fall 2008 for planted and seeded plots separated by a) Site b) Species c) Management regime.

Table 4: Univariate ANOVA results (α=0.05) of root collar diameter measurements for planted and seeded trees

Planted					Seeded				
Source of variation	df	MS	*F*	*P*	Source of variation	df	MS	*F*	*P*
Site	2	1.654	76.132	≤0.000	Site	2	0.176	6.995	0.001
Species	2	0.101	4.668	0.001	Species	2	0.134	5.325	0.006
Management	2	0.262	12.064	≤0.000	Management	2	0.110	4.370	0.014
Site * Species	4	0.527	24.253	≤0.000	Site * Species	3	0.031	1.224	0.302
Site * Management	4	0.098	4.527	0.001	Site * Management	4	0.213	8.442	≤0.000
Species * Management	4	0.082	3.759	0.005	Species * Management	4	0.050	1.997	0.096
Site * Species * Management	7	0.063	2.912	0.006	Site * Species * Management	3	0.029	1.152	0.329
Error	286	0.022	.	.	Error	224	0.025	.	.

DISCUSSION

The site treatment heavily impacted all the analyses. Seed germination, seedling survival, incremental height growth and root collar diameter growth were all significantly greater for the Pittock site. Soil texture class is the logical explanation for this phenomenon. The sandier soil at the Pittock site provided an ideal growing environment for the oak species while providing adequate drainage to support consistent improvement for the black cherry seedlings. Also black cherry prefers sites with higher coarse fragment content (Marquis 1991), which was the case at the Pittock site. The Fingal and Littlejohn sites had a higher content of silt and clay in the soil which when saturated provided poor growing conditions for the moisture intolerant black cherry, and inferior growing conditions for the oak species when compared to a sandier soil. This discovery supports most work in the afforestation field which suggests that matching the tree species to site type is the best way to ensure a successful plantation (von Althen 1991, Groninger 2005).

The planting method factor indicates that three years of data collection for seeded plots is not enough time to produce comparable results to planted stock even if the data was standardized. The large initial root mass common to planted stock does not develop naturally in such a short period. With the stressful environment that abandoned fields present, the rapid development of a root system becomes especially challenging. However, the potential for directly seeded trees to catch up to planted stock is not lost. With the slow growing nature of these hardwood species it may be difficult to detect comparable results within the first 10 years after planting (Sander 1991).

The vegetation management results suggest that plastic mulch can match or even exceed the performance of herbicide use in terms of average height increment growth, RCD growth and seedling survival. The plastic mulch treatment did not perform well for the seeded plots but this does not suggest that the practice is inappropriate for direct seeding. Variable germination success is common for directly seeded plantations (von Althen 1991). With proper site preparation, directly seeded plantations could be left until the fall or spring after planting before applying the mulch. This would improve germination success and reduce the likelihood of investing money in a vegetation management practice where no trees are present. Plastic mulch is an expensive vegetation management option thus postponing its application may be a wise management practice.

Although the oak species are from the same genus they performed quite differently in the field trial. The silvics of bur oak indicate that it is very sensitive to flooding (Johnson 1991, Cogliastro *et al.* 2003). With the high silt and clay content of the Fingal and Littlejohn sites bur oak is likely to perform poorly. The black cherry results indicate that this species is suitable for afforestation only when planted. The germination requirements for black cherry are strict and because it can seed bank for up to three years after sowing, a homogenous and successful plantation is unlikely. The planted results show that black cherry seedlings consistently produce good growth regardless of the response variable especially at the Pittock site. Black cherry's traits as a generalist species enable it to grow and occupy a site rapidly and its survival rates suggest that it is able to withstand a competitive environment.

CONCLUSION

As interest in afforestation in southern Ontario increases, more landowners will be faced with critical decisions pertaining to the success of their plantations. There are a number of services available to the public who wish to afforest their land in Ontario but there is very little published research on proven techniques for the do-it-yourself landowner. In this paper we confronted three typical decisions made when undertaking afforestation. We have demonstrated the potential for plastic mulch as an effective alternative to herbicide use without the annual application commitment. We identified red oak as an appropriate tree species for afforestation and bur oak as a species whose success in afforested plantations seems limited by site quality and hydrology. We also demonstrated the potential that planted black cherry has for quickly occupying and persisting on an afforested site. A clear conclusion on the success of direct seeding was unable to be formed due to the age of our plantations. However, when comparing the germination percentages and the survival percentages in our study, the possibility for the directly seeded trees to persist and become mature still exists.

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